Jet Propulsion Laboratory
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Potential Antarctic contribution to sea level due to uncertainties in ice sheet model forcing and dynamic feedbacks

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Study Motivation:

What should we measure?

Where should we measure?

- to improve projections of sea level change

- to make the strongest impact to improve confidence in projections

We use the

Ice Sheet System Model (ISSM)

to numerically model complex, non-linear responses of ice flow, ice thermal properties, and migration of floating ice grounding lines

and

the ISSM-DAKOTA framework

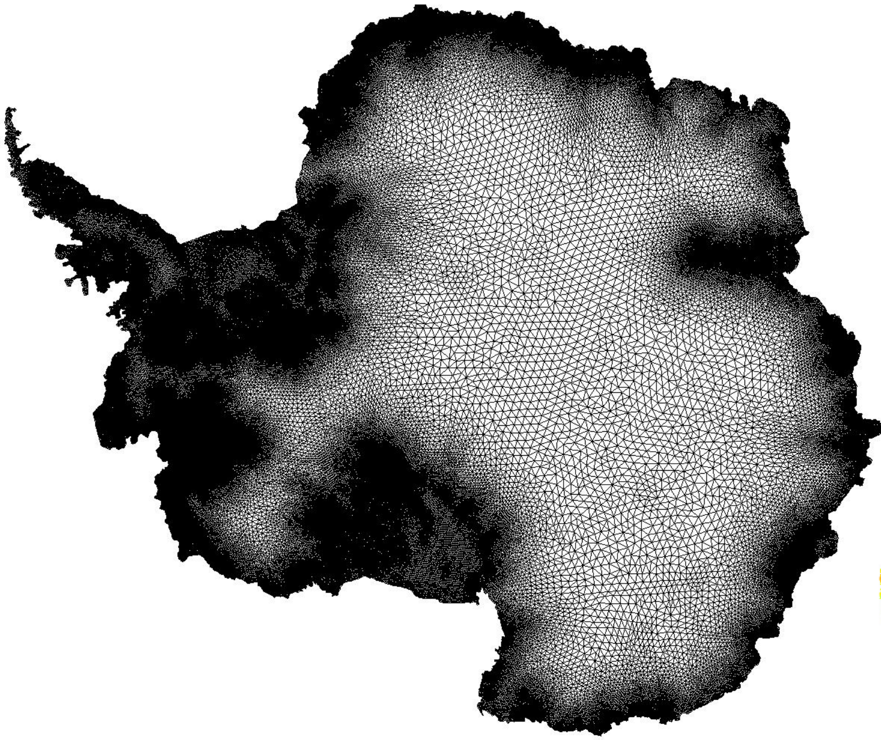
for uncertainty quantification analyses

Method: investigate *propagation of uncertainties* in ice sheet model projections of future sea level

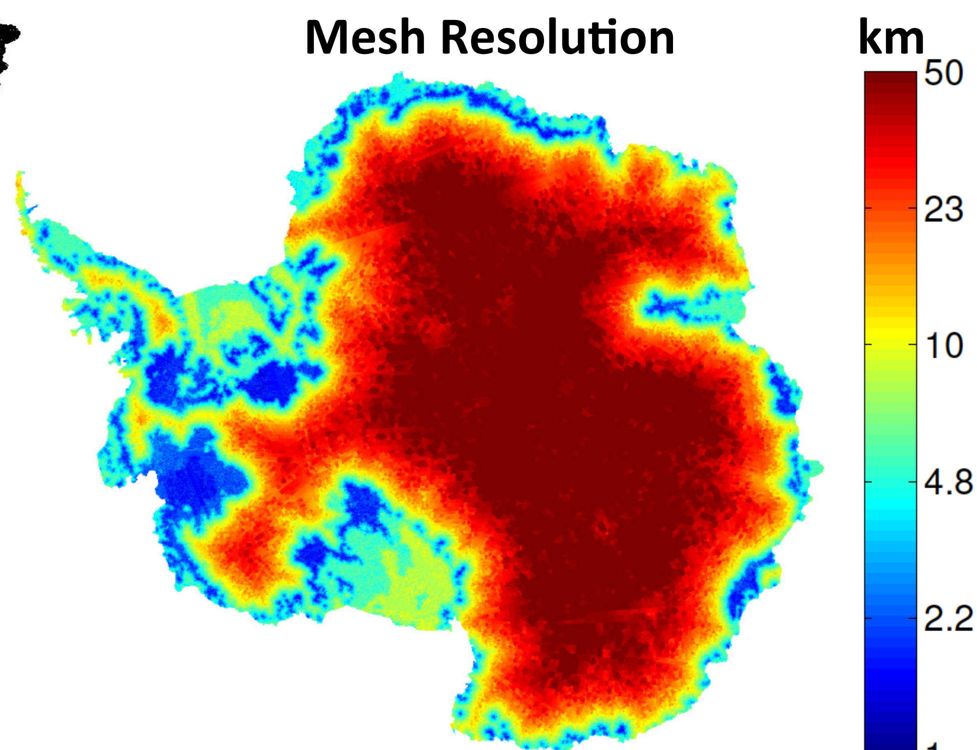
Introduction of the Antarctica Ice Flow Model:

ISSM Antarctica

ISSM Antarctica uses a finite element, anisotropic triangular mesh



999,719 finite elements:
- < 1 km at shear margins
- 50 km at the divides
- At least 1.5 km, in proximity to region of grounding line migration for 200-yr simulation



ISSM Antarctica is initialized to a present-day state

KEY MODEL INPUT/DATA:

ACCUMULATION

- *Climate forcing RACMO2.1 mean annual 1979-2010*

ICE SHELF MELT RATES

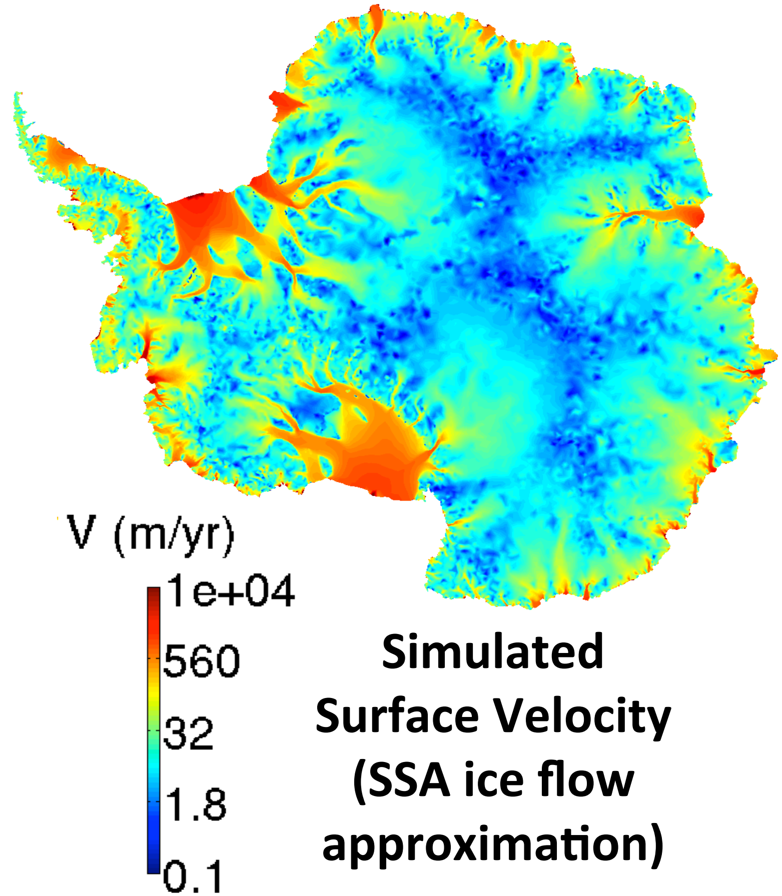
- *Mean annual from ECCO2-MITgcm 150-layer 9 km (2004-2013)* [Schodlok et al., GRL (2016)]

BASAL SLIDING and ICE TEMPERATURE

- *Inversion to match observed ice surface velocities* [Rignot et al., *Science*, 2013]

BEDROCK and SURFACE TOPOGRAPHY

- *Bedmap2*, Amundsen Sea, Recovery, and Totten bed mapped using mass conservation* [Morlighem et al., GRL (2011); Rignot et al., GRL (2014)]

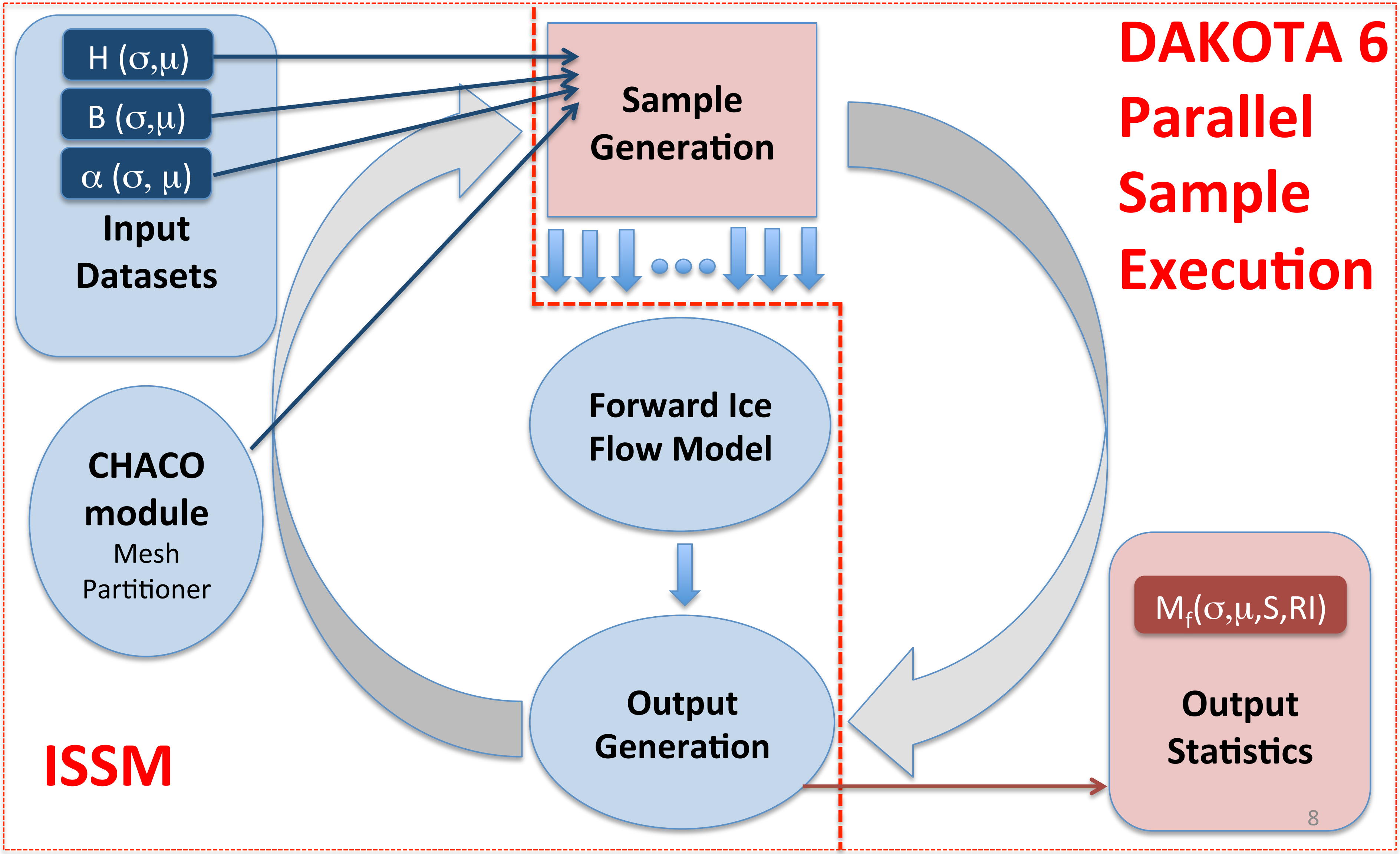


Simulated Surface Velocity (SSA ice flow approximation)

Uncertainty Quantification Techniques:

ISSM-DAKOTA FRAMEWORK

Design Analysis Kit for Optimization and Terascale Applications (DAKOTA) software is embedded into ISSM



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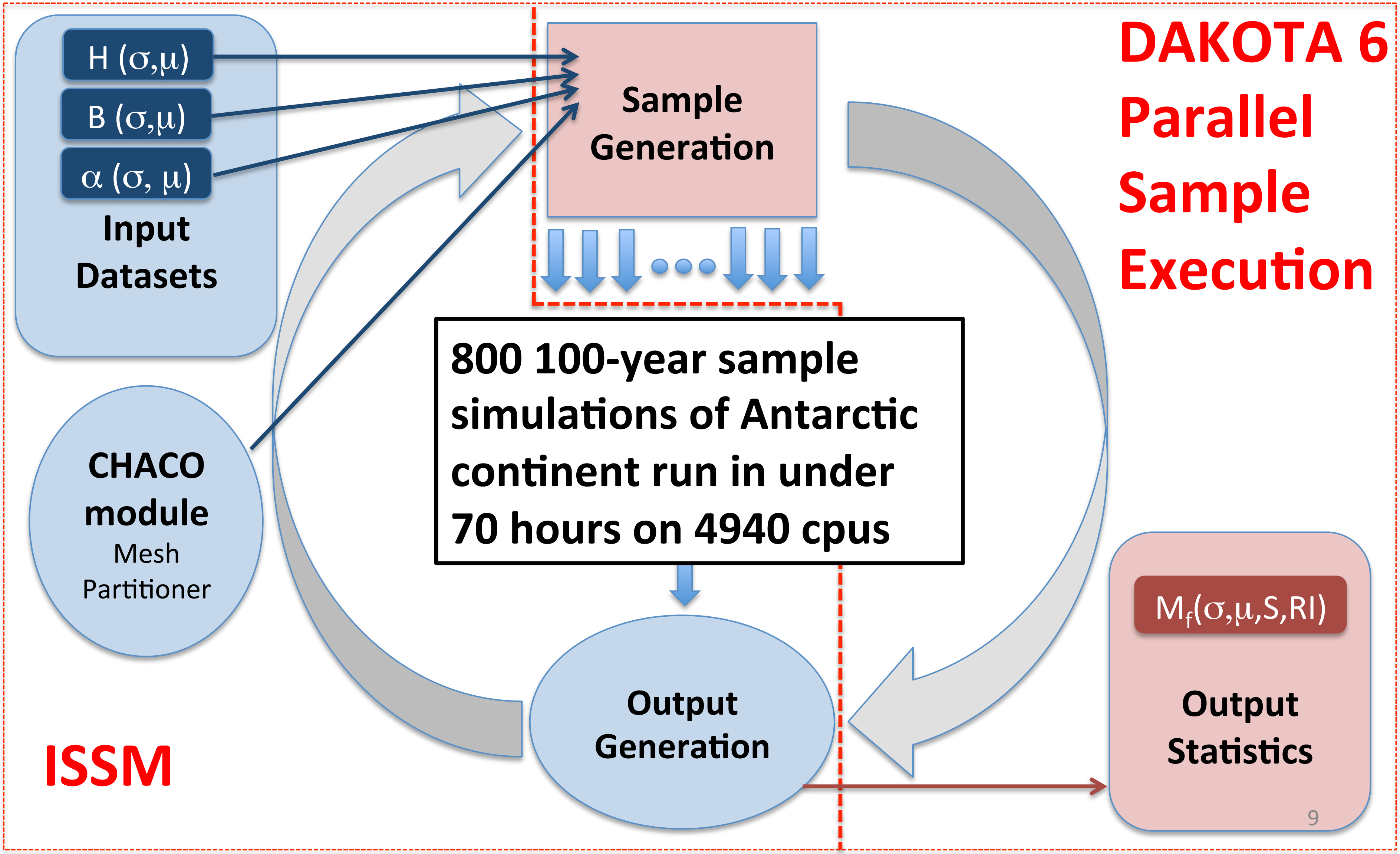


Continental-Scale Utility of

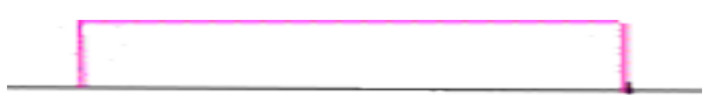
SAMPLING ANALYSIS

What are the sources of uncertainty in projected extreme changes in regional 100-year Sea Level Equivalent (SLE) contribution from Antarctica?

We statistically test the effect of errors in four key model variables by bounding them with a range of realizations from present day to extreme values relative to present day control

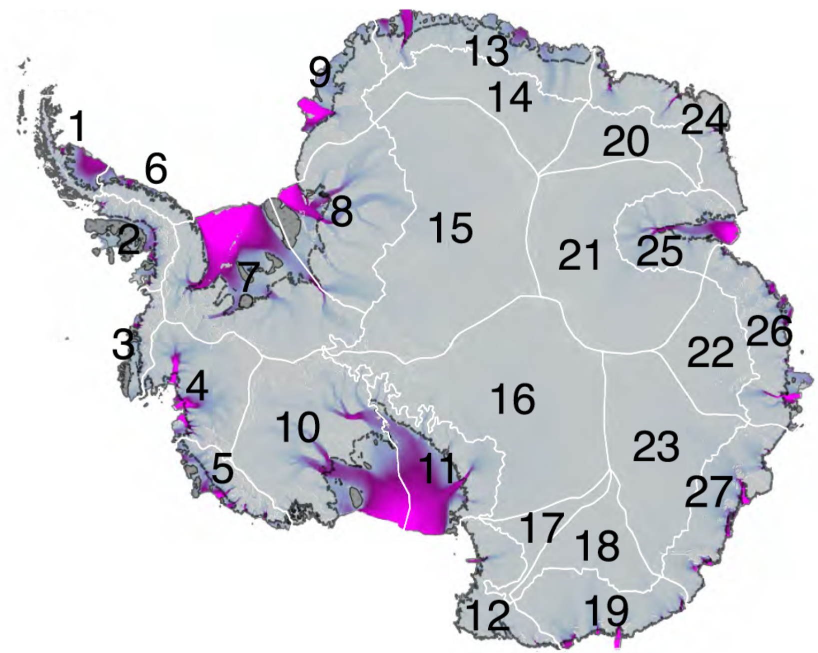
Variable	Extreme Scenario Multiples of Present
Ice Shelf Melt	10 times melt rate
Basal Sliding	2.5 times faster
Ice Viscosity	40% less viscous
Accumulation	2 times snowfall

Uniform Sampling



Present day Extreme

27 Geographic Regions sampled independently during every one of the 800 simulations in each ensemble



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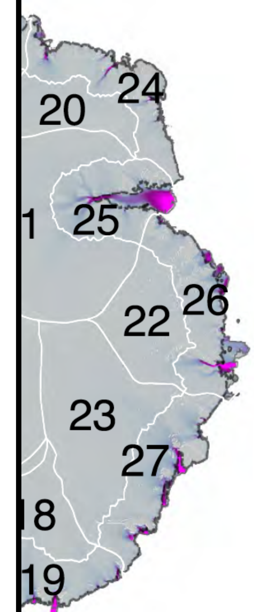


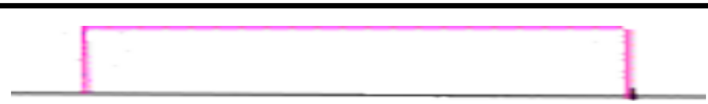
STRATEGY:

⇒Sample each variable individually

⇒Sample all variables simultaneously

(Vary Melt, Basal Sliding, Ice Viscosity, and Accumulation all at the same time)

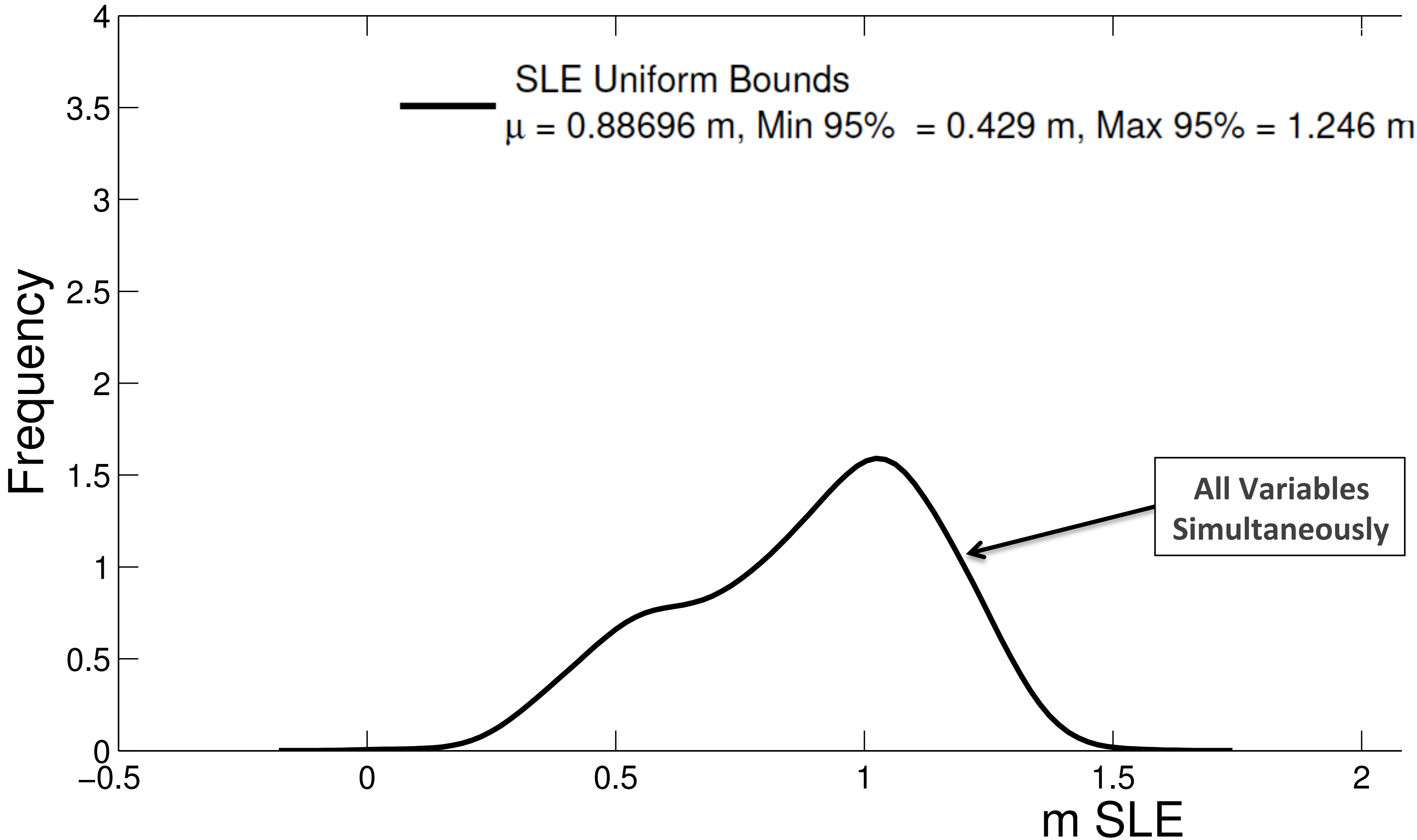
All perturbations applied as a step function



Sampling Analysis:

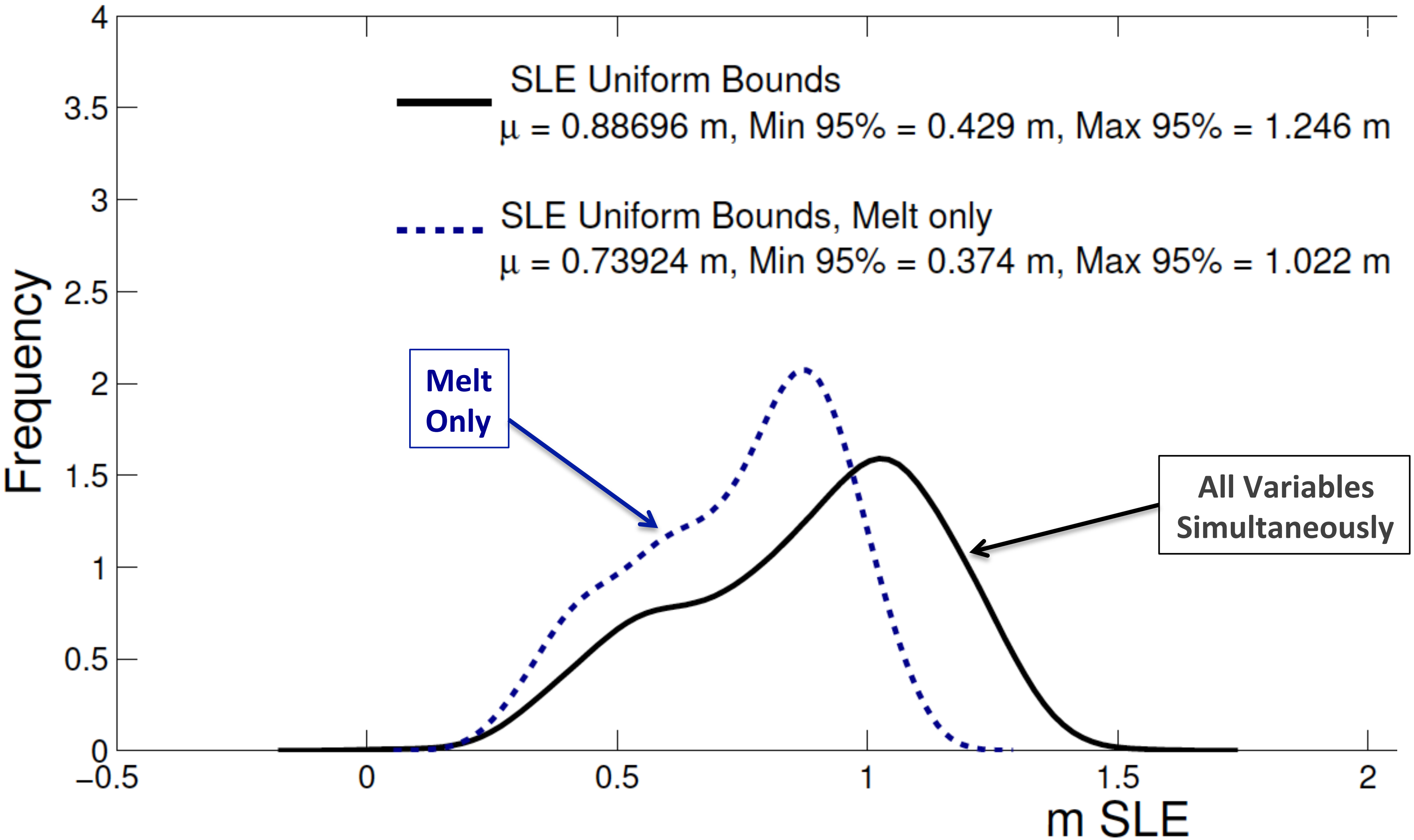
UNCERTAINTY IN SEA LEVEL CONTRIBUTION

Resulting SLE contributions for 800, 100 yr simulations, reveal a bimodal distribution



[Schlegel et al., Cryosphere (2018)]

Ice Shelf Melt is responsible for a majority of the spread, and for the complex, bimodal distribution

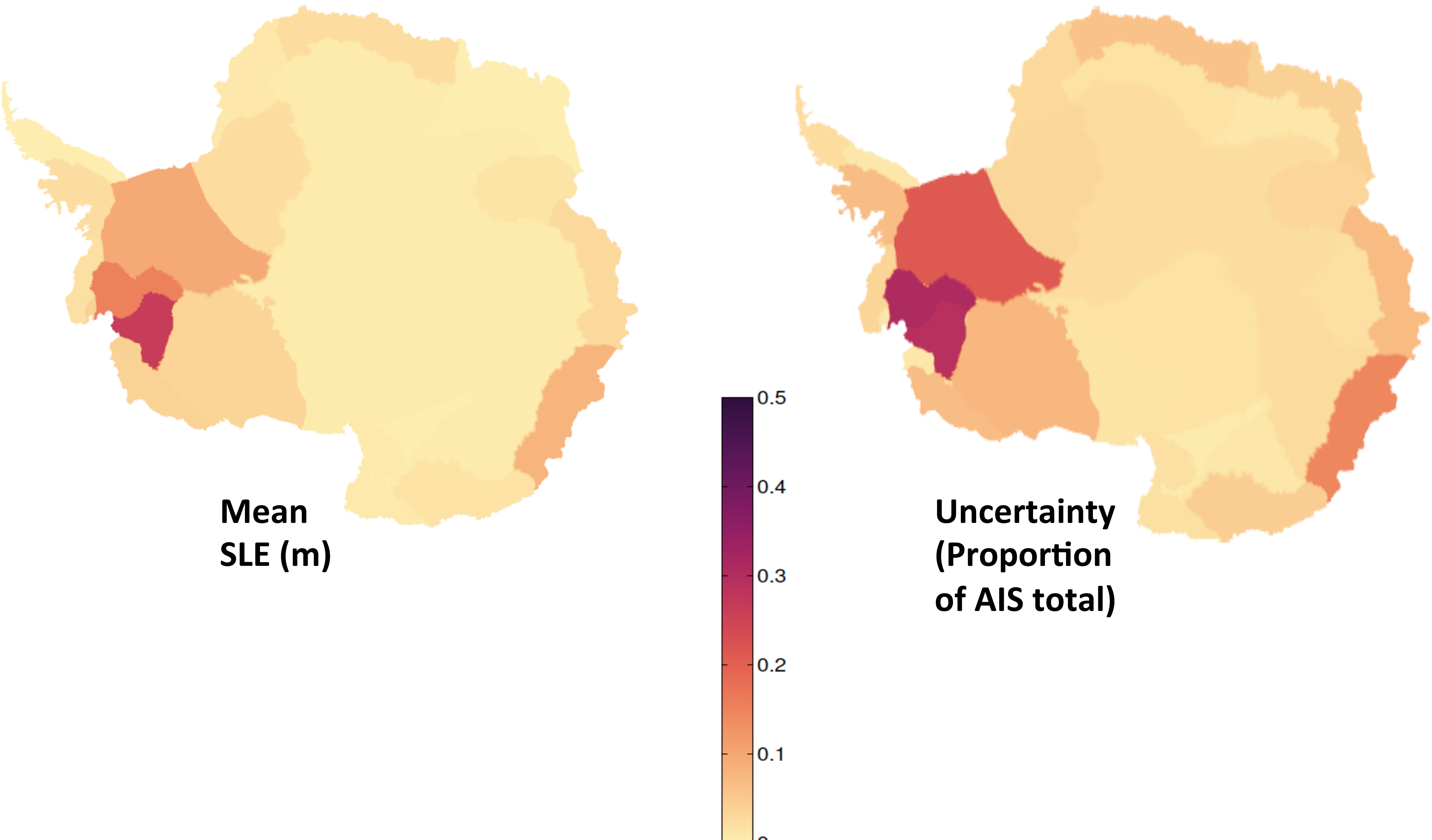


[Schlegel et al., Cryosphere (2018)]

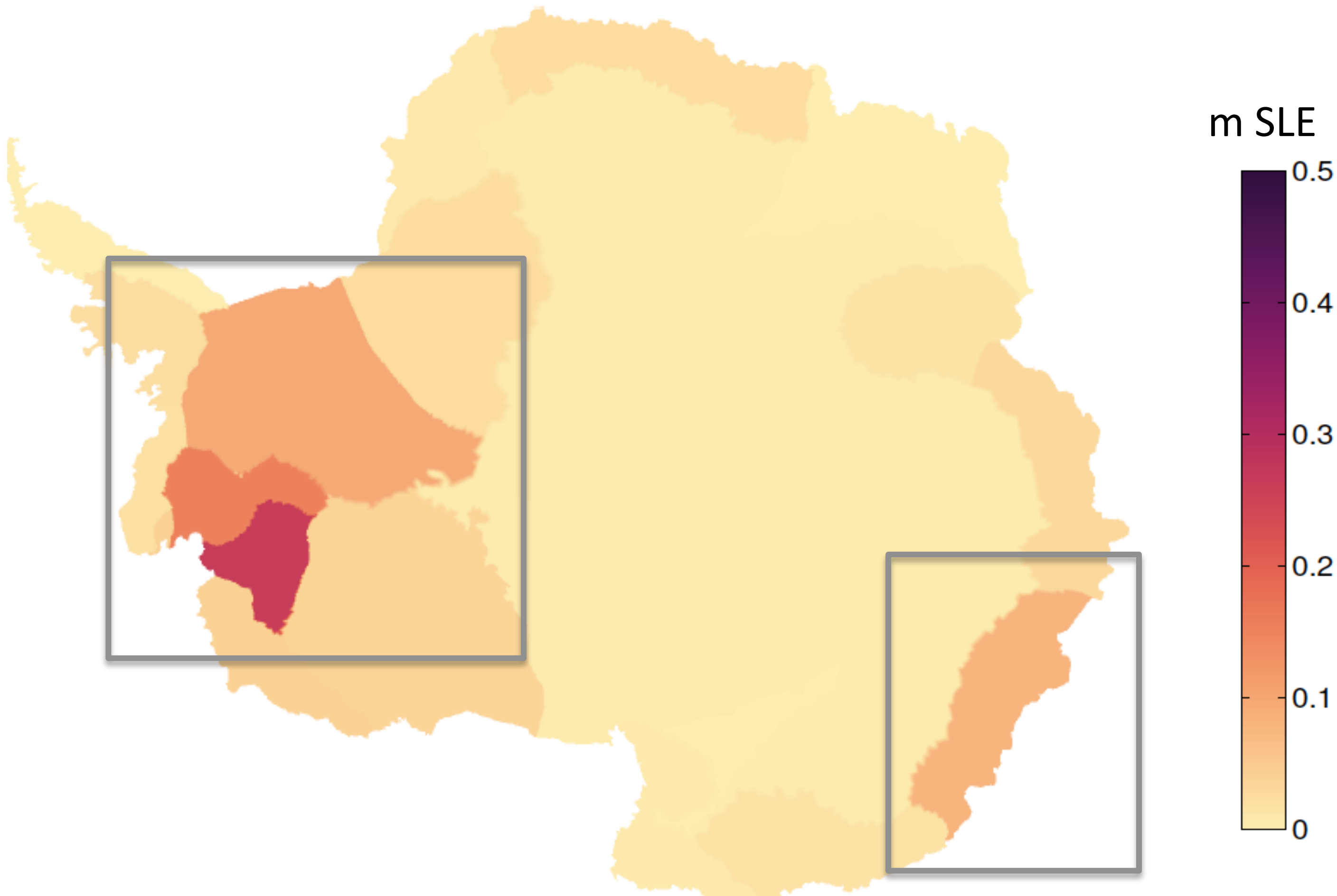
Regional Analysis:

UNCERTAINTY IN SEA LEVEL CONTRIBUTION

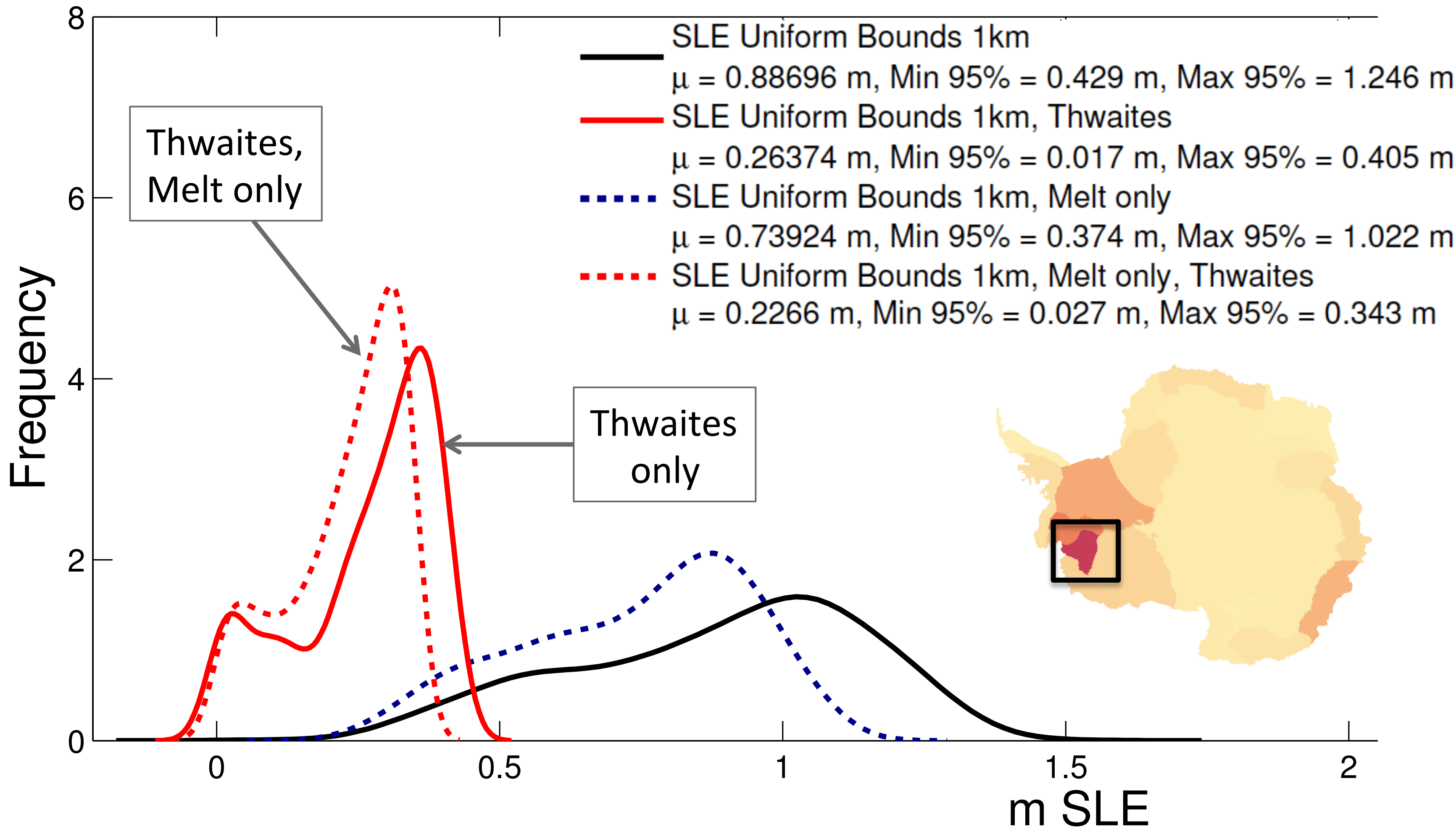
SLE contributions and their uncertainties vary regionally



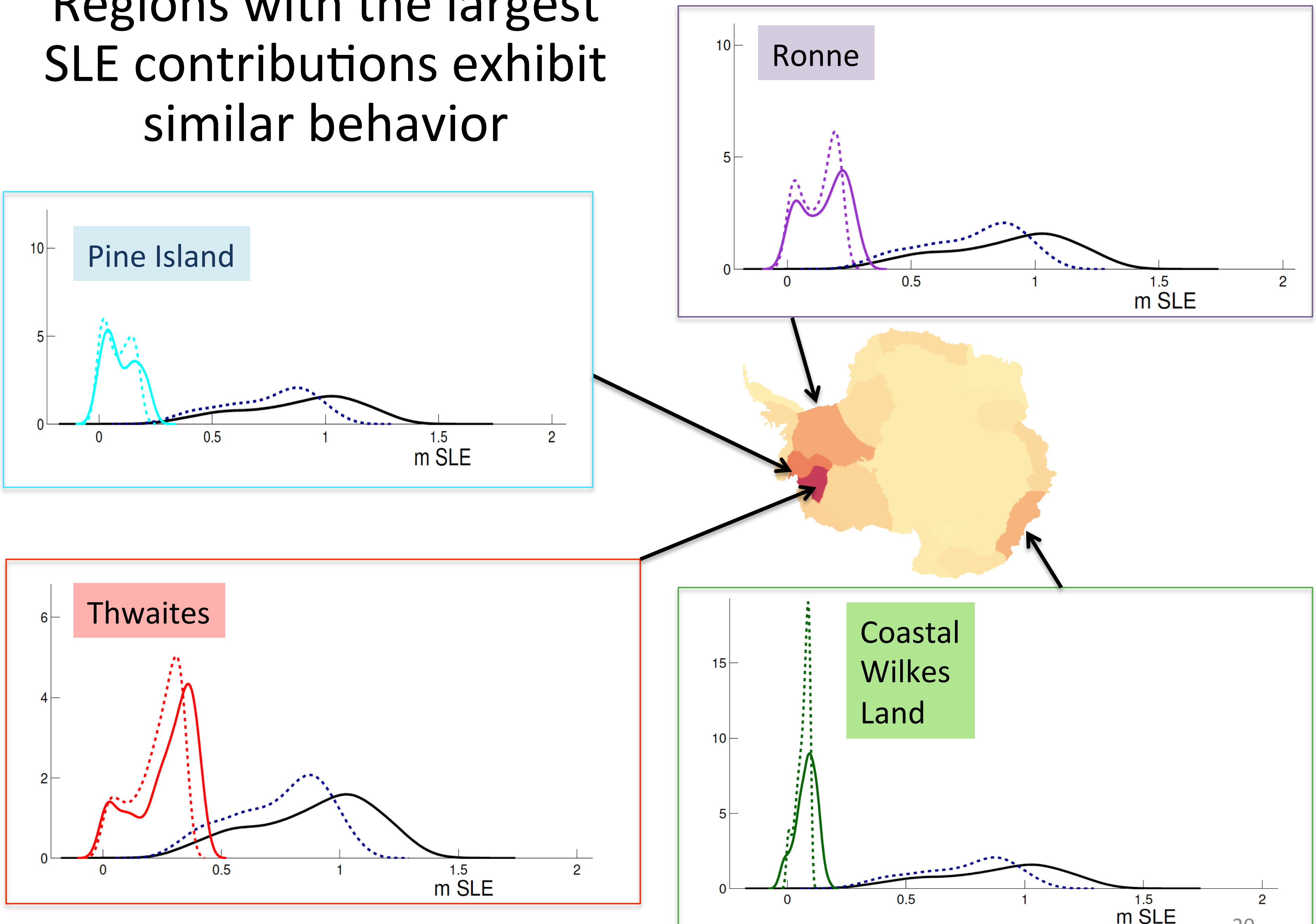
Mean SLE contribution by region highlights West Antarctica and coastal Wilkes Land



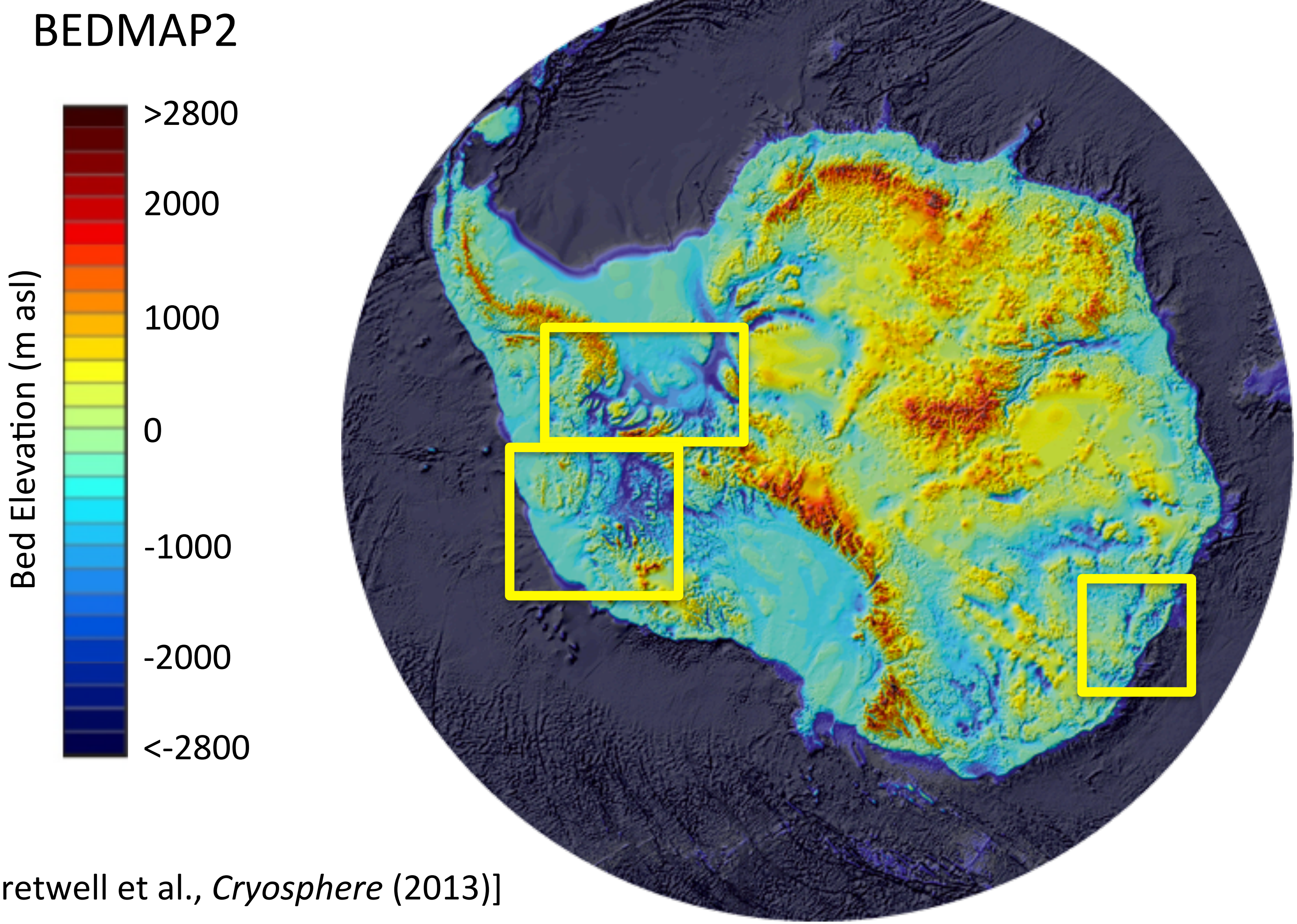
The response to ice shelf melt rates in Thwaites accounts for a majority of the uncertainty and bimodal behavior of the continental ice sheet SLE signal



Regions with the largest SLE contributions exhibit similar behavior



The most sensitive regions also correspond to complex, deep bedrock

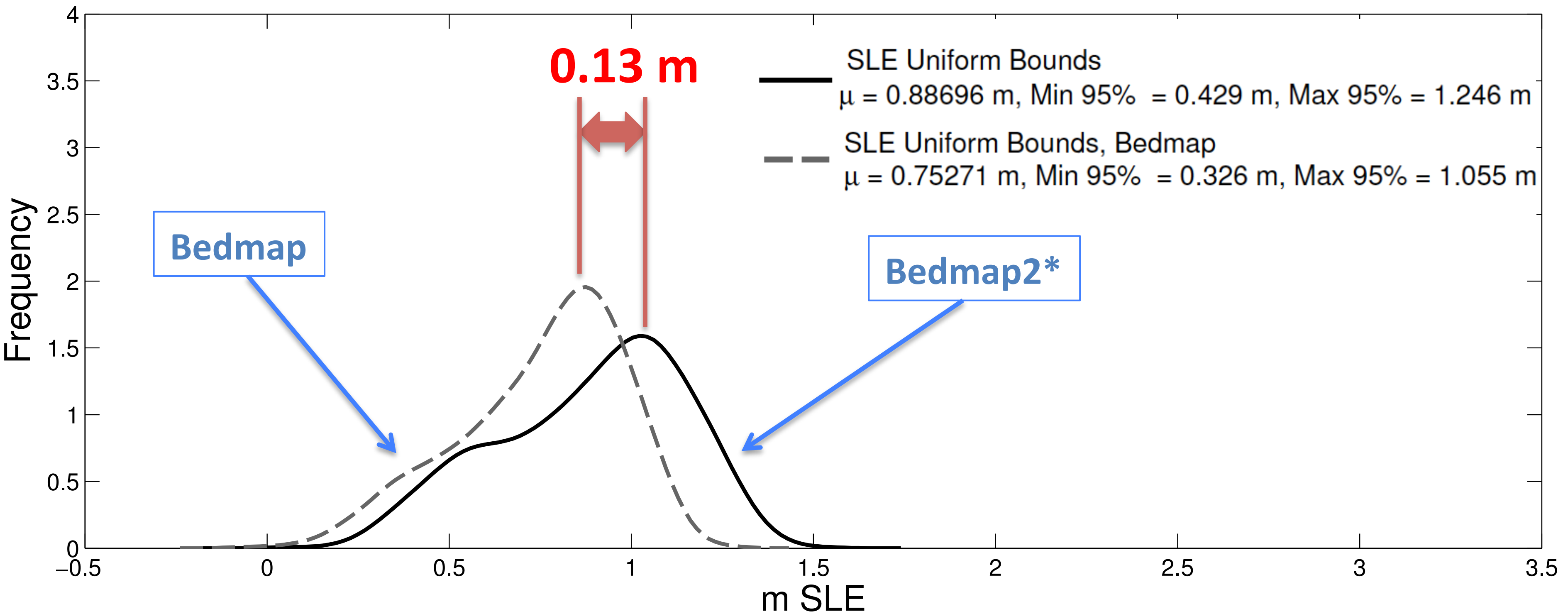


[Fretwell et al., *Cryosphere* (2013)]

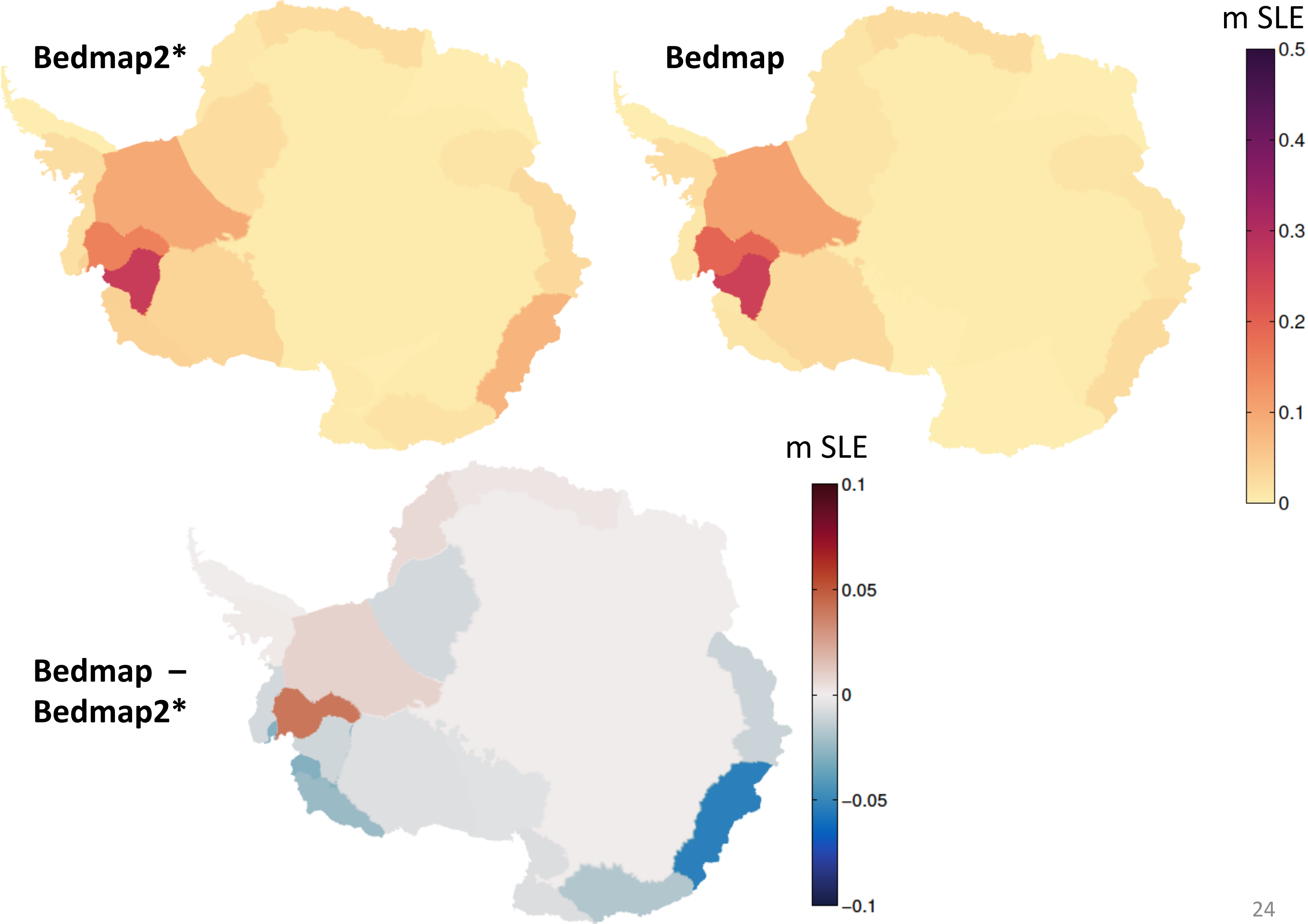
Additional Analysis:

UNCERTAINTY DUE TO BEDROCK TOPOGRAPHY

Use of Bedmap topography instead of Bedmap2 bedrock can lead to a ~15% underestimate in projection of sea level contribution (SLC)



Regional results reveal that the use of Bedmap does not lead to an underestimate in SLC for all regions



Conclusions

- ✓ 1.2 meter of sea level contribution is achievable but not likely
- ✓ Uncertainties and sources of uncertainty vary regionally and are complex
- ✓ Resulting SLE PDFs represent:
  - a ramification of forcing, boundary conditions, and input
  - a combined consequence of various regional responses of many individual glaciers

What should we measure?

Continued measurements/improvement of bedrock topography and better analysis/observation of melt rates under ice shelves are critical for projections

Where should we measure?

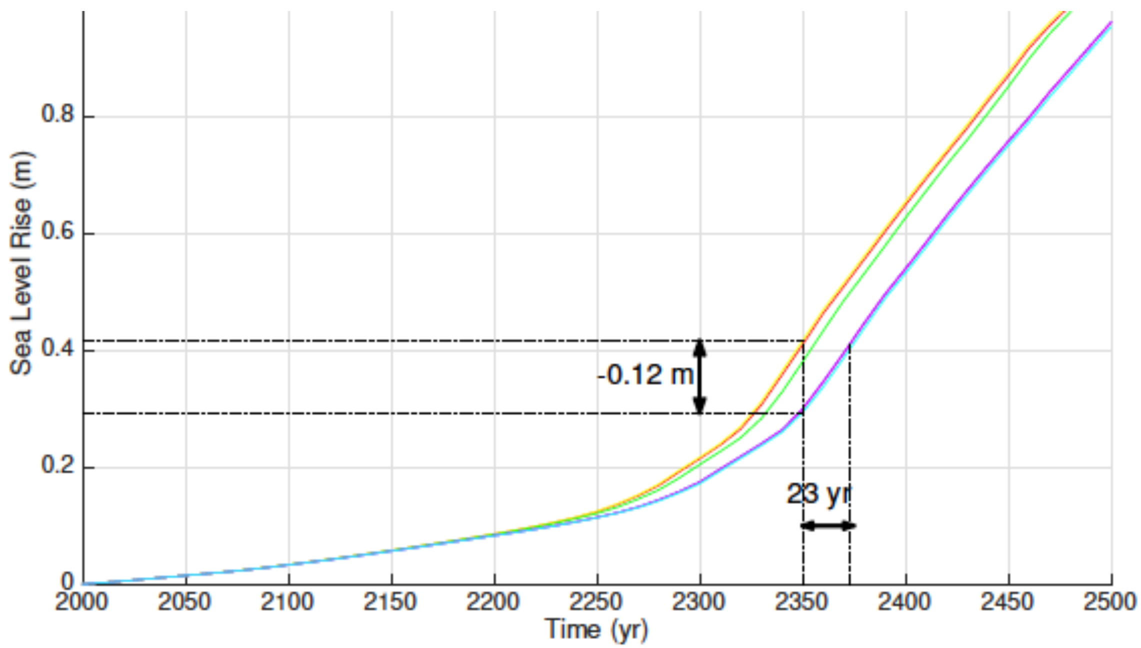
Amundsen Sea, Ronne Ice Shelf, and coastal Wilkes Land (i.e. Totten) are areas on which to focus in the future, in terms of observations and modeling

Future Work

⇒ Coupling Uncertainty Quantification tools with ISSM sea level core to simulate solid-Earth feedbacks. Requires high spatial resolution and multi-century forward runs.

SEE

C33A-08: Slowdown in Antarctica Mass Loss from Solid-Earth and Sea-Level Feedbacks
Eric Larour, Wednesday, 15:25 - 15:40



Above: A run including all solid-Earth processes (blue) including all solid-Earth processes, can be delayed in sea level contribution by ~23 years by 2350. [Larour et al., 2018, in review]

Thank you!